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Inferring Ultraviolet Anatomical Exposure Patterns while Distinguishing the Relative Contribution of Radiation Components

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Exposure to solar ultraviolet (UV) radiation is the main causative factor for skin cancer. UV exposure depends on environmental and individual factors, but individual exposure data remain scarce. UV irradiance is monitored via different techniques including ground measurements and satellite observations. However it is difficult to translate such observations into human UV exposure or dose because of confounding factors (shape of the exposed surface, shading, behavior, etc.)

A collaboration between public health institutions, a meteorological office and an institute specialized in computing techniques developed a model predicting the dose and distribution of UV exposure on the basis of ground irradiation and morphological data. Standard 3D computer graphics techniques were adapted to develop this tool, which estimates solar exposure of a virtual manikin depicted as a triangle mesh surface. The amount of solar energy received by various body locations is computed for direct, diffuse and reflected radiation separately. The radiation components are deduced from corresponding measurements of UV irradiance, and the related UV dose received by each triangle of the virtual manikin is computed accounting for shading by other body parts and eventual protection measures.

The model was verified with dosimetric measurements (n=54) in field conditions using a foam manikin as surrogate for an exposed individual. Dosimetric results were compared to the model predictions. The model predicted exposure to solar UV adequately. The symmetric mean absolute percentage error was 13%. Half of the predictions were within 17% range of the measurements. This model allows assessing outdoor occupational and recreational UV exposures, without necessitating time-consuming individual dosimetry, with numerous potential uses in skin cancer prevention and research.

Using this tool, we investigated solar UV exposure patterns with respect to the relative contribution of the direct, diffuse and reflected radiation. We assessed exposure doses for various body parts and exposure scenarios of a standing individual (static and dynamic postures). As input, the model used erythemally-weighted ground irradiance data measured in 2009 at Payerne, Switzerland. A year-round daily exposure (8 am to 5 pm) without protection was assumed.

For most anatomical sites, mean daily doses were high (typically 6.2-14.6 SED) and exceeded recommended exposure values. Direct exposure was important during specific periods (e.g. midday during summer), but contributed moderately to the annual dose, ranging from 15 to 24% for vertical and horizontal body parts, respectively. Diffuse irradiation explained about 80% of the cumulative annual exposure dose. Acute diffuse exposures were also obtained for cloudy summer days. The importance of diffuse UV radiation should not be underestimated when advocating preventive measures. Messages focused on avoiding acute direct exposures may be of limited efficiency to prevent skin cancers associated with chronic exposure (e.g., squamous cell carcinomas).